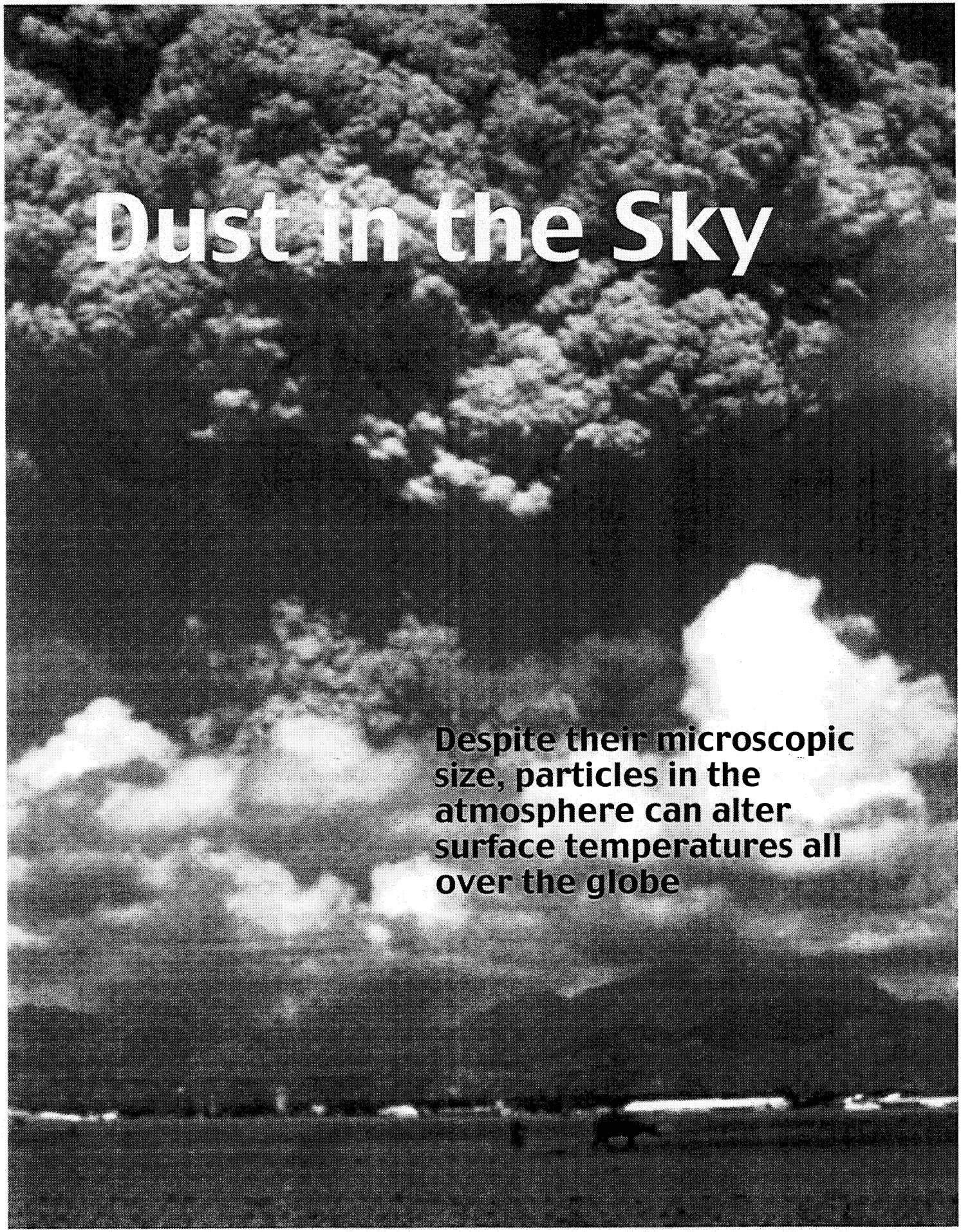


Dust in the Sky

Despite their microscopic size, particles in the atmosphere can alter surface temperatures all over the globe

An *aerosol* is any small particle of matter that rests suspended in the atmosphere. Natural sources, such as deserts, create some aerosols; consumption of fossil fuels and industrial activity create other aerosols. All the microscopic aerosol particles add up to a large amount of material floating in the atmosphere. You can see the particles in the haze that floats over polluted cities.

Beyond this visible effect, aerosols can actually lower temperatures. They do this by blocking, or *scattering*, a portion of the sun's energy from reaching the surface. Because of this influence, scientists study the physical properties of atmospheric aerosols. Reliable numerical models for atmospheric aerosols play an important role in research.

Aerosol basics

For the most part, aerosols that scientists study reside in the *troposphere*, the portion of our atmosphere that lies between 15 and 45 kilometers above the surface. Particles remain at this altitude until they absorb enough moisture from the atmosphere and gain enough mass to sink back to the surface.

The following are the major types of aerosols:

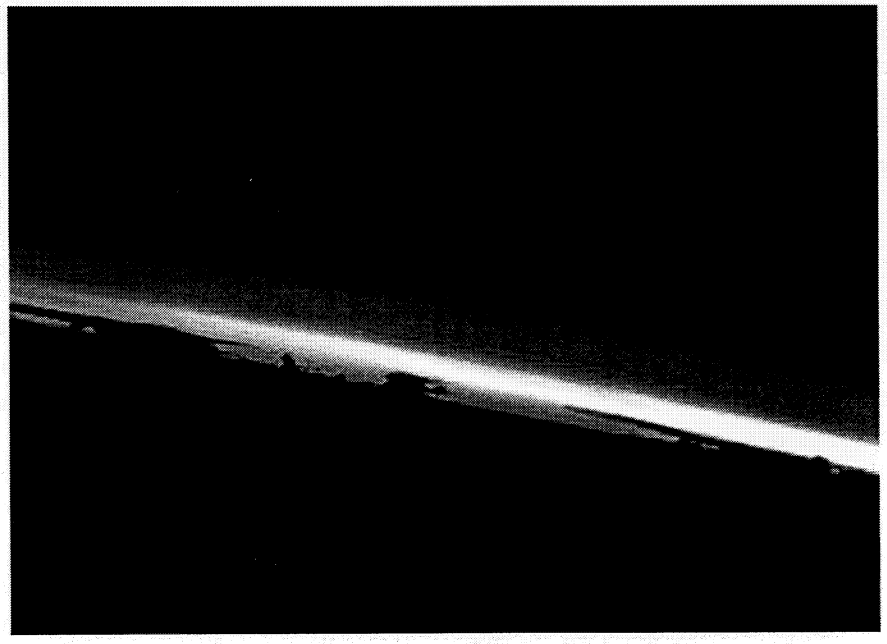
- *Sulfate* is produced mostly from fuel combustion and industrial activity. Volcanic eruptions and the burning of biomass also produce sulfate.
- *Dust* is carried into the air from deserts and other dry plains.
- *Sea-salt*, like dust, is lifted from the ocean by wind. It does not remain in the air long before absorbing enough moisture to sink back down to the surface.
- *Organic carbon* (OC) and *black carbon* (BC) are created mostly from the burning of vegetation.

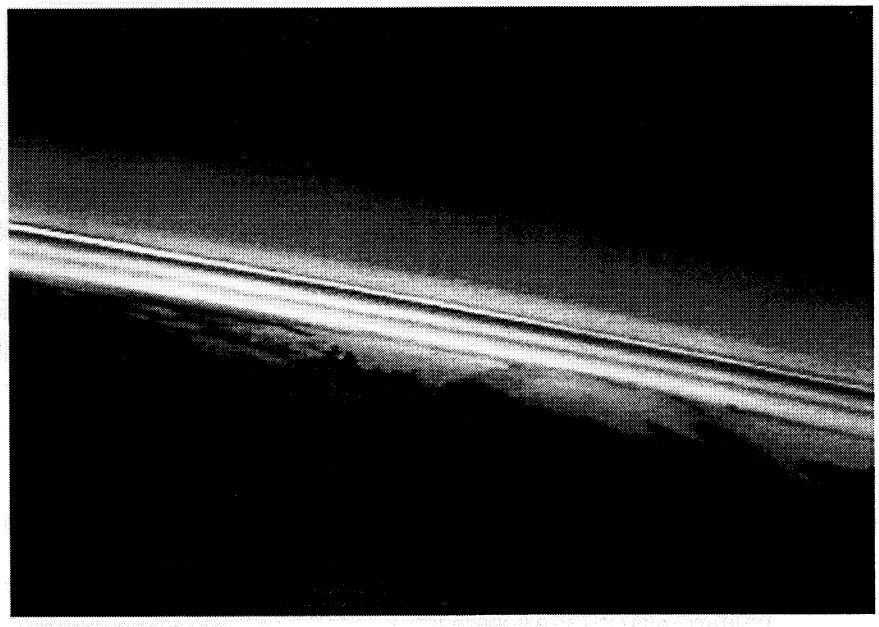
The distribution of aerosols varies by both location and season. For example, dust is usually the predominant aerosol type over the deserts of northern Africa. However, carbon aerosols are more common in this area during the winter months, when biomass burning is more common.

Aerosol optical thickness (AOT) is the primary measurement by which scientists determine the amount of aerosol material in the skies. It quantifies the amount of light, at a particular wavelength, that the aerosol is blocking at a specific location. The types of aerosols produced in an area, the ability of those aerosol particles to grow by absorbing moisture from the air, and the wind currents that carry aerosols are all factors that determine AOT.

Measurement of aerosols

Over the past 20 years, a number of space-based and ground-based monitoring programs have





The volcanic eruption of Mount Pinatubo hurled a tremendous amount of ash and other particles into the atmosphere over the Philippines. This aerosol layer is visible in the sunset photo (top), taken in August 1991, 1 month after Pinatubo's eruption. In comparison, a similar photo taken in August 1984 shows much less material in the sky. *Image credit: NASA Johnson Space Center*

monitored the level of aerosol material in the atmosphere:

- The Total Ozone Mapping Spectrometer (TOMS) program observes atmospheric aerosols, ozone, solar radiation reflected from the Earth, and ultraviolet radiation. The Atmospheric Chemistry and Dynamics Branch at the NASA Goddard Space Flight Center manages the TOMS program.
- The Advanced Very High Resolution Radiometer (AVHRR) scans the visible, infrared, and near-infrared spectrums. AVHRR is carried aboard the Television and Infrared Observation Satellite (TIROS)-N and operated by the National Ocean and Atmospheric Administration. Two methods are used to extract AOT from the AVHRR's radiation measurements.
- Unlike the previous satellite observing systems, the Aerosol Robotic Network (AERONET) is ground based. Sunphotometers record light at more than 100 locations around the world. The AERONET data collections are made of single-point recordings rather than global-scale ones.

Each of these measurement systems has limitations. Ground systems are limited to covering only areas where stations are located. Satellite systems can maintain a global range, but they do not provide as many details about specific aerosol types. Furthermore, light that is reflected off land may interfere with readings. Nevertheless, these measurement systems are useful for verifying the accuracy of numerical models.

Reference

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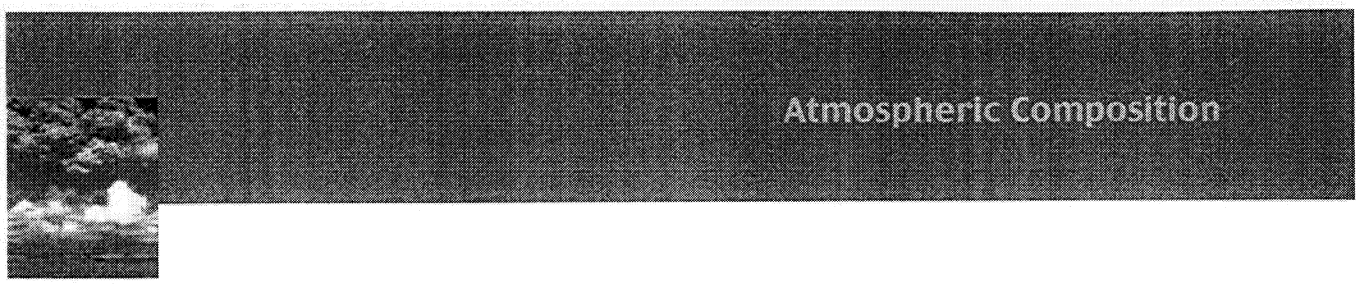


Research Profile: Modeling of Aerosol Optical Thickness

Investigators:
Mian Chin, Paul Ginoux, Stefan Kinne, Omar Torres, and Brent Holben, NASA Goddard Space Flight Center; Bryan Duncan, Randall Martin, and Jennifer Logan, Harvard University, Department of Earth and Planetary Studies; Akiko Higurashi, National Institute for Environmental Studies; and Teruyuki Nakajima, University of Tokyo, Center for Climate System Research

These researchers tested the accuracy of the Georgia Tech/Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model against observation records.

GOCART simulates AOT at the 500-nanometer (nm) wavelength for major types of tropospheric aerosols. These global calculations include a breakdown of AOT by altitude and aerosol type. The resolution grid of this model provided 8 to 10 times the detail of previous modeling attempts. Only supercomputing centers such as the NCCS can provide such fine detail in numerical simulations.

GOCART calculates AOT from the mass of aerosol material in a particular location, as well as from the aerosol's *mass extinction efficiency*, that is, a measurement of the ability of the aerosol to absorb or scatter light. Mass extinction efficiency depends on the type and size of the aerosol, as well as the amount of moisture that the aerosol has absorbed.

The scientists fed meteorological data on wind, temperature, pressure, humidity, cloud flux, and precipitation from 1990, 1996, and 1997 into the model. Scientists also used data on fuel combustion from the Emission Database for Global Atmospheric Research (EDGAR).

The GOCART results noted that AOT was highest over northern Africa, where dust is normally the predominant aerosol type. A large plume of dust that blows over the Atlantic Ocean from Africa stands out in the graphs that depict AOT totals. Sulfate predominated over high-pollution areas such as eastern North America, Europe, and eastern Asia. Biomass burning made carbon the primary aerosol over Brazil, Africa, and southern Asia.

To identify the areas from which dust aerosols originate in the model, scientists used a new approach. The basic premise of this approach is that the depth of a nonflat, bare surface increases the likelihood of dust accumulation that wind can carry into the atmosphere. The new method has successfully located major dust sources in deserts and dried lake basins around the world.

A new biomass burning database was used to estimate the emission of black carbon, organic carbon, and other tracers from biomass burning activities. This new database was based on the location of fires recorded in satellite

observations. Therefore, the location, time, and amount of material released from biomass burning can be estimated much more effectively than ever before.

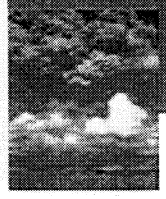
The scientists compared GOCART's results against measurement records from TOMS, AVHRR, and AERONET. Overall, the scientists report agreement within a factor of two. The correlation is closest in areas with high AOT and areas where a single aerosol type dominates.

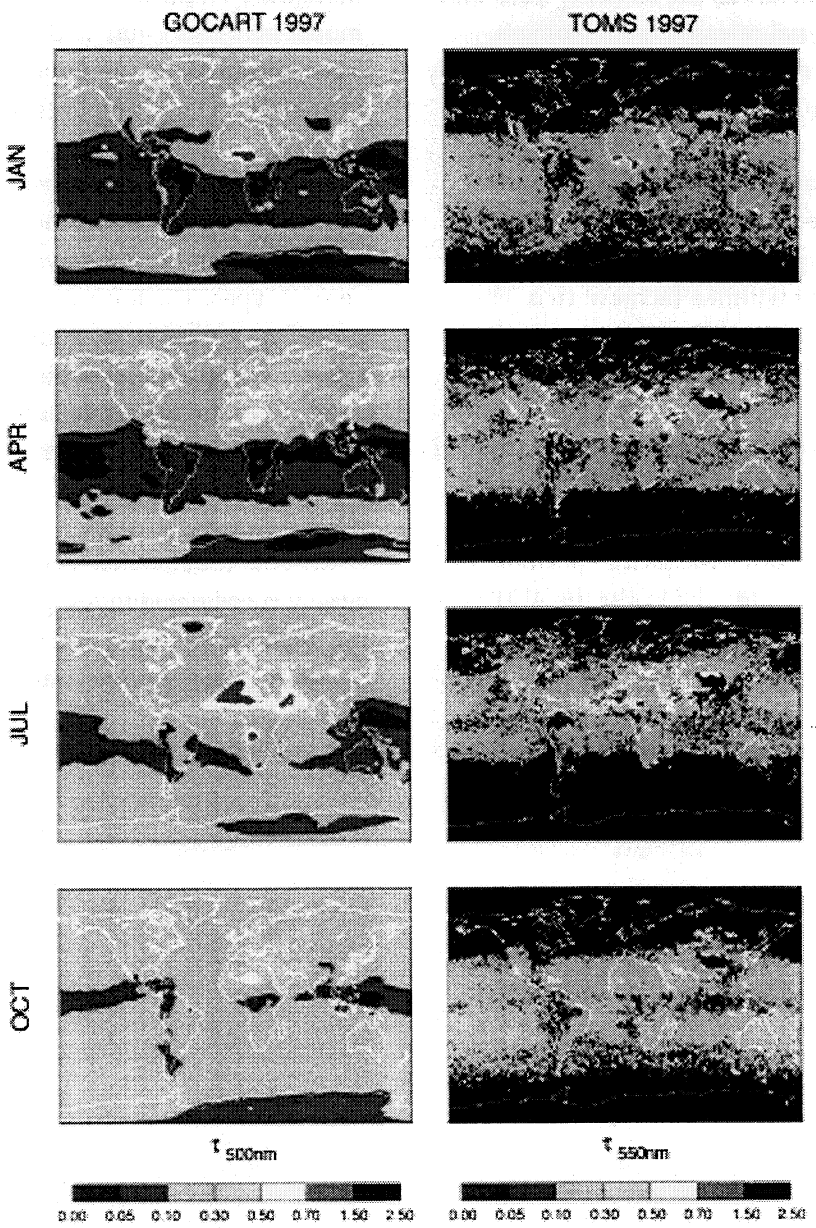
Outside these areas, interpreting model results is still difficult. For example, the model shows a sharp latitudinal drop-off in AOT over the oceans. In other words, the farther north or south from the Equator, the lower the AOT gets. However, this drop-off is not registered in the observation records.

Furthermore, the AERONET readings suggest that the model's set background level of dust is inaccurate. According to this comparison, the model may overestimate the AOT in areas with little aerosol matter and underestimate the AOT in areas with large amounts of aerosol matter.

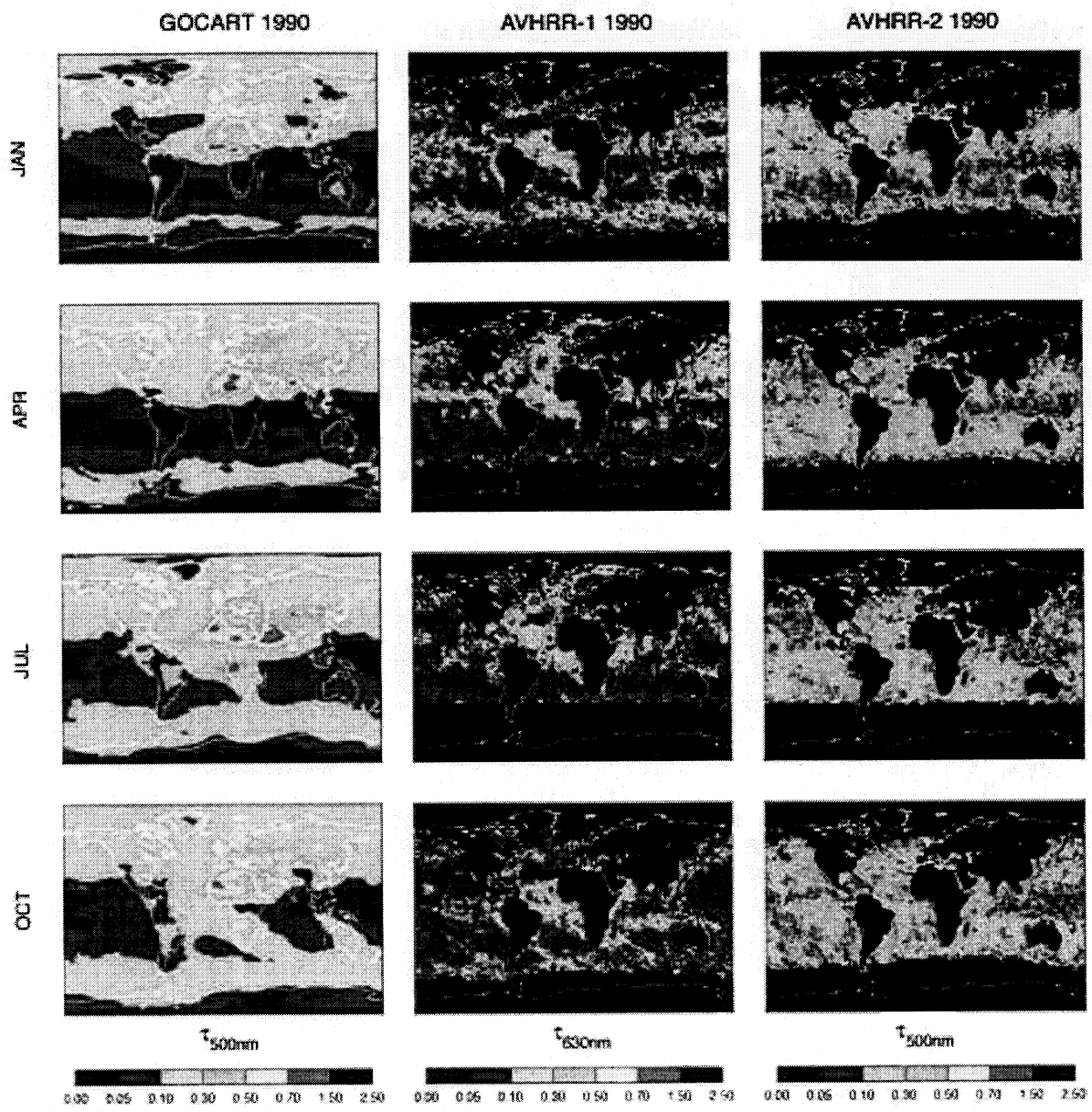
One complication in this comparison stems from the manner in which the model or the satellite retrieval quantifies the physical properties of the aerosol types. The formulae that represent these properties are based on a limited number of measurements. For example, a constant value is assigned to the refractive index of dust, regardless of the kind of mineral that actually composes the dust.

In the end, the researchers concluded that more closely coordinated investigations among modeling, field experiments, and satellite retrieval would reduce the uncertainties in AOT modeling.





These data maps show the monthly composites of AOT measurements throughout 1997. The left column shows the calculations of the Georgia Tech/Goddard GOCART model; the right column displays the satellite retrievals from the TOMS. Both results place the highest AOT values over Africa, where vegetation is burned in the latter half of the year and desert dust blows over the Atlantic Ocean.



The GOCART calculations for AOT are compared to the measurements of the AVHRR for the year 1990. Researchers used two different techniques to retrieve measurements from the raw AVHRR data: one-channel and two-channel. Neither AVHRR retrieval produced readings over landmasses because the visible wavelengths that AVHRR measures are not reflected evenly by land.